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Statistical evaluation of the composition, physical properties, and surface configuration of terrestrial test sites and their correlation with remotely sensed data

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RESEARCH WORK UNDERTAKEN

As mentioned in the previous report (#1), extensive sampling was carried out by the Northwestern University team at the Pisgah Crater Geological Test Site, California, in March, 1965. This sampling was undertaken to investigate some of the underlying statistical problems associated with defining a precise and accurate picture of the 'ground truth' of selected areas. It is becoming increasingly obvious that this work is a prerequisite in any attempt to correlate remotely-sensed data with geological ground information.

Most of our effort since the last Semi-Annual Status Report (March 31, 1965) was involved with laboratory work, experiment, and data analysis based on the field observations, photographs, and samples collected at Pisgah in March, 1965. The original target of producing an initial report on the analytical results and observations from one small sampling grid (number 1) within the Pisgah Test Site proved unrealistic; more textural data from lithologically-distinct areas were needed in order to substantiate early tentative conclusions.

The data for four of the eight sampling grids laid out by Northwestern University at the Pisgah Site (grids 1, 4, 7, and 8; see map in Report #1) have now been analyzed in detail. The resulting information forms the basis of a technical report which is presently in the final stages of writing and illustration; because this complete manuscript will be submitted for publication in the immediate future, only a brief summary of the work is included here.

The laboratory work was divided into two sections:

(a) Analysis of photographic samples: Each of approximately 200 Kodachrome transparencies was projected (at actual sample size) onto a one-inch grid; these photographs are vertical shots of pre-selected localities chosen according to a statistical design. Projection permitted point-counting in order to determine the distribution and areal variability of textural grades on the ground surface of the sampled sites. An attempt was made to measure the size of the detrital material and to sort the fragments according to the Wentworth grade scale. Five attributes were measured on each photograph: sand and finer material, pebbles, cobbles, lava flow, and vegetation. Material finer than sand could not be resolved on the photos, and color definition was too poor to obtain measurements that could be correlated with the lithology of this fine-grained fraction. The operator effect was examined; recounting the samples by the same and by different operators showed that reproducibility of the results is relatively very good.

(b) Lithologic sample analysis: Approximately 125 lithologic samples were dry-sieved and separated into 0.5 phi classes (from -2 phi to 4 phi). The size distributions were analyzed with an IBM 709 computer program (SIDISPRO); the weight percentages and their statistical moments, phi mean, phi standard deviation, skewness, and kurtosis, were among the attributes measured at each sample point. The specific gravity of some of the finer grain-size grades were also measured with an air-comparison pycnometer. Chemical analyses for six oxides (SiO_2, total Fe, MgO, CaO, Na_2O, and K_2O) were carried out for 23 surface lithologic samples and for three segments of a vertically stratified sequence of samples.

For each of the four sampling grids at Pisgah the data derived from both the photographs and from the lithologic samples were analyzed with a normalized-matrix computer program (ZITZ) to obtain mean percentages and the statistical moments, the variances of the attributes, and a correlation-coefficient matrix. Trend-surface analysis was also used to evaluate the nature of the areal variability of each measured attribute within each sampled grid. Components-of-variance statistical models were erected - using several different combinations of the measured attributes - in order to estimate the magnitude and the level of variability associated with the different sample sites and the different modes (photographic and lithologic) of estimating the nature of the sampled populations. For each attribute, the relative size of the within-sample-site (local) and the between-sample-site (regional) variability was determined.

Although very limited information is available to date, the results of our chemical analyses indicate significant compositional variation within relatively small increments of depth below the atmosphere-lithosphere interface.

This work leads to the following observations about the variability at the atmosphere-lithosphere interface at the Pisgah Crater Test Site:

1. In our experiments a relatively low data interlock between the attributes measured is indicated by linear correlation analyses.

2. Trend surfaces account for only a small proportion of the total sum of squares associated with each measured attribute (with one exception); commonly such results in other studies have been found to be associated with large local variability within the sampled population of objects.

3. Data were obtained from photographic (mode A) and from lithologic (mode B) samples from three sample sites (1, 4, and 7); these

sites were initially chosen to have dissimilar sample-point spacing and dissimilar geological interest. Components-of-variance analysis results are very significant and showed greater differences between mode A and mode B data for each sample point of each site, than between sample points of the site when examined by either mode A or by mode B alone; these relationships hold for sampling based on sites 1, 4, and 7. These results suggest that, if different sensors respond to different geological attributes, it is necessary to define an appropriate geological target population separately for each sensor experiment and thus to sample in a manner appropriate to that population.

4. Within the limits prescribed by our experiments, limited variation in the size of the surface area sampled does not significantly affect the values of the attributes measured at each location. However, in many cases, analyses of replicate samples (collected a few feet from the initial samples), resulted in data arrays significantly different from those for the original samples.

The last two points (3 and 4) emphasize that considerable additional work is needed before precise and accurate statistical models can be erected (within specified confidence limits) for geological attributes of a test site. The problem lies in the fact that essentially no information exists about the variance of measurable geological attributes studied in samples of various sizes and at various spatial relationships. It must be emphasized that these problems lie in a largely-unexplored domain of geology. However, with the addition of Dr. Hobson as a full-time member of the Northwestern University team as of September 1, 1965, we are making a concerted effort to investigate the statistical 'behavior' of a wide variety of attributes measured at a variety of NASA and other sites. The results should prove invaluable in attempting to unravel the statistical problems involved in correlating remote sensor data with the actual geological site sensed (the ground truth).

Numerous novel techniques are being experimented with - for example, analyzing the roughness and terrain characteristics from 1:180 air photos. Encouraging results are being obtained, and these will be incorporated in subsequent detailed reports.

REPORTS, FIELD WORK, CONSULTATIONS, AND CONFERENCES

Work completed:

1. Interim Progress report #1 (period to March 31, 1965) - 24 pages - was issued on April 7, 1965.
2. Manuscript and illustrations (total of 146 pages) for a NASA publication were completed and sent to NASA Headquarters on July 15, 1965. The proposed title was: "A surface-fitting program for areally-distributed data from the earth sciences and remote sensing."

Meetings attended:

1. Symposium on post-Apollo space exploration presented by American Astronautical Society, Chicago, Illinois, May 4-6, 1965; attended by W. A. Beckman.
2. Geoscience Test Site NASA Committee, Menlo Park, California, May 10-11, 1965; attended by E. H. T. Whitten.
3. Symposium on the physics of the moon and its environment presented by The Royal Society, London, England, June 3-4, 1965; attended by A. L. Howland (who happened to be in Britain at the time).

Consultations:

1. Field visit to Atomic Energy Test Site (Buckboard Mesa), Mercury, Nevada, to study photographic imagery interpretation of cratering experiments (Interpretation work by Waterways Experiment Station - Operation Ploughshare), June 18-19, 1965; visit by E. H. T. Whitten.
2. Selection of sedimentary-rock site for NASA fundamental test site: Flight over proposed NW Arizona site and attempted flight over proposed central Utah site (latter curtailed by bad weather) with Dr. Lintz (Reno); visit by E. H. T. Whitten.
3. Conference in the field (Nevada) with Dr. Lintz (Reno) on actual problems associated with sampling and establishing 'ground truth': July 5-6, 1965; visit by E. H. T. Whitten.

Field work:

1. NW Arizona sedimentary geological test site: photographic and lithologic sampling in field; September 7-9, 1965; by R. D. Hobson. Followed by overflight of proposed High Sierra Nevada, California, test sites with Dr. Lintz (Reno).
2. Mono Craters and Sonora Test Sites, California, studied and sampled, September 27 through end of report period; visit by R. D. Hobson.